Beaked Whale Presence, Habitat, and Sound Production in the North Pacific

John A. Hildebrand
Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA 92093-0205
phone: (858) 534-4069 fax: (858) 534-6849 email: jhildebrand@ucsd.edu

Mark A. McDonald
WhaleAcoustics
11430 Rist Canyon Rd
Bellvue, CO 80512
phone: (970) 498-0448 email: mark@whaleacoustics.com

Award Number: N000140910489
http://www.cetus.ucsd.edu

LONG-TERM GOALS

The project is motivated by the need to understand beaked whale distribution and habitat, and the need for classification of these species from passive acoustic data. By studying beaked whale presence, habitat and sound production, the Navy will be better prepared to conduct environmental impact assessments in the North Pacific, a region of significant training activity. In addition, fundamental information will be gained on beaked whale foraging ecology.

OBJECTIVES

Our objective is to construct an abundance estimate and distribution map of beaked whale presence in the southern California region, based on long-term passive acoustic monitoring data. Our primary effort focuses on Cuvier's beaked whales, whose acoustics are well known, but whose distribution is not. Another focus is on all the other beaked whale species in the North Pacific, whose acoustic signatures have not been well characterized. Better knowledge of beaked whale distribution and abundance is expected to lead to better understanding of the niche habitats of each beaked whale species, allowing use of environmental correlates to interpret distribution maps.

APPROACH

Passive acoustic monitoring provides an alternative to conventional sighting surveys for assessing beaked whale populations. With Navy support, we have been conducting long-term passive acoustic monitoring with High-frequency Acoustic Recording Packages (HARPs) in the southern California region for the past few years. These data reveal ample acoustic signatures from beaked whales, characterized by a frequency swept echolocation pulse. At least nine species of beaked whale are known to occur in southern California waters, mostly based on stranded animals (Dalebout et al., 2007;

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Mitchell, 1968). The most abundant beaked whale species off Southern California is Cuvier's as evidenced by fishery bycatch and visual sighting surveys. Other beaked whale expected to be present include Baird's, Blainville's, Ginkgo-toothed, Perrin's, Hubb's, Pygmy, Stejneger's and Longman's.

Acoustic signatures are known for only three of these beaked whales, though species distinctive echolocation signatures probably exist for all these species. Cuvier's beaked whales produce frequency modulated echolocation pulses with mean inter-pulse intervals of 0.4 s and durations of about 200 µs. The upswept pulses have center frequencies at 42 kHz and -10 dB bandwidths of 22 kHz (Zimmer et al. 2005). Blainville's beaked whale has a similar echolocation signal, but with a sharper cutoff of energy below 25 kHz (Johnson et al., 2006). Baird's beaked whale has an echolocation click whose mean duration is about 500 µs and whose largest spectral peak is between 22 and 25 kHz with a second largest spectral peak between 35 and 45 kHz (Dawson et al., 1998).

Our approach for beaked whale population estimation is a cue count method. The basic unit for analysis is one foraging dive for either a group of beaked whales or a single beaked whale. Due to the highly directional nature of beaked whale echolocation, we do not expect to continuously detect the echolocation sounds, depending on which direction the animals are pointed. We estimate the number of echolocating animals in the group using the echolocation data, and thereby derive an acoustic estimate for group size. At each site, we estimate the average number of foraging dives per day. The overall density of Cuvier's beaked whales in the southern California study area can be estimated by first calculating the number of animals within the detection radius of each HARP, and then dividing by the effective monitoring area, following Zimmer *et al.* (2008). We further examine the setting of each site to better understand how to extend beaked whale habitat to the larger southern California region.

WORK COMPLETED

We have studied 1800 days of acoustic recording data, from 11 different sites in the southern California region. Based on spectra, start frequency, end frequency, rate of frequency modulation and inter pulse interval, the detections of Cuvier's beaked whales were separated from echolocation associated with other species of dolphins or beaked whales. Greater than 95% of the beaked whale detections in the southern California data match those of Cuvier's beaked whales; the other 5% are either indistinct or distinctly different. Some of these we attribute to Baird's beaked whale, but the remaining are without known species correlation.

RESULTS

We have found a substantial number (3707) of Cuvier's beaked whale dives in the southern California dataset. We compare relative density of foraging beaked whales using a dives/day unit of measurement. The average number of dives/day for each site, versus the bathymetric profile arranged from shallowest to deepest, is shown in Figure 1. The number of days of recordings analyzed for each site is also noted. Because there is no directional information associated with the Cuvier's beaked whale detections, the depth and density correlations consider the entire bathymetric profile within the 3 km maximum detection range. The bathymetric profiles in Figure 1 were chosen to illustrate the maximum depth range at each site. It is apparent that Cuvier's beaked whale foraging habitat requires water depth of at least 1000 m. Sites with water depths less than 1000 m show almost no Cuvier's beaked whale forging echolocation.

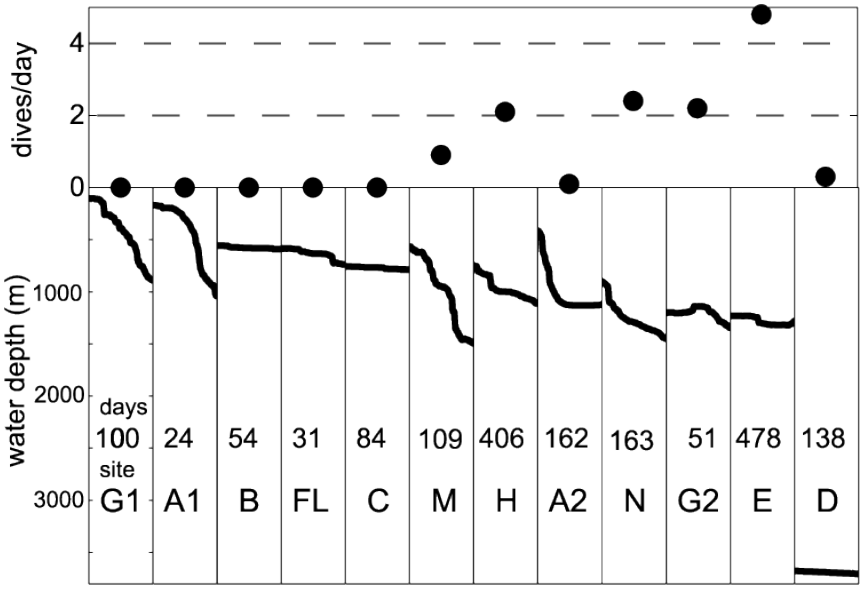

Figure 1. Plot of dives/day versus bathymetric profile for each site in the southern California study area. The plotted water depths are perpendicular to the slope for a 3 km radius, the maximum acoustic detection range.

On the other hand, 1000 m water depth alone is not sufficient to predict the presence of Cuvier's beaked whales, as seen by the variability of foraging dives/day at the deep sites in Figure 1. Cuvier's beaked whale distributions may be additionally controlled by prey distributions, which in turn may be related to oceanographic parameters such as oxygen level. Squid distributions are thought to positively correlate with low oxygen levels to avoid fish predation (Gilly, 2006).

In addition to Cuvier's and Bairds's beaked whales, at least three distinctive beaked whale signals with unknown species association have been found; we characterize them by their dominant frequency as: 43, 50 and 65 kHz. The "43 kHz beaked whale" signal has similar spectral properties to Cuvier's beaked whales, but with shorter inter-pulse interval and other variations in echolocation signal type not seen in Cuvier's beaked whales. The "50 kHz beaked whale" signal is distinctly higher in frequency than Cuvier's beaked whale. The "65 kHz beaked whale" signal is found both in southern California and in the Gulf of California, and may be produced by a species similar to Pygmy's beaked whale, which is frequently encountered in the Gulf of California, or another warm water beaked whale.

IMPACT/APPLICATIONS

The ability to conduct marine mammal population estimates and habitat assessments using acoustic monitoring provides a complimentary means for study of marine mammal populations. This is particularly important in the context of monitoring naval training ranges, and the potential impact of range activities on marine mammal populations.

RELATED PROJECTS

Project title: Southern California Marine Mammal Studies; Sponsor: CNO N45 and the Naval Postgraduate School; Support from this project allowed for the development of HARP instrumentation and collection of the acoustic data processed for beaked whales with ONR support during N000140910489.

Project title: SBIR Topic N07-024 Marine Mammal Acoustics; awarded to Sonalysts; Sponsor: NavAir PMA264; Support from this project has allowed analysis of sonar exposure levels for Cuvier's beaked whales and their impact on foraging.

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